Attorney's Case No. 6-3714

SOLENOID REGULATED PUMP ASSEMBLY

This application claims the benefit of U.S. Provisional Application No. 60/427,094 filed November 18, 2002.

FIELD OF INVENTION

The invention relates to pump assemblies and methods for pumping high-pressure liquid, typically engine oil or fuel, for actuating fuel injectors, inlet and exhaust valves and other devices in internal combustion engines.

DESCRIPTION OF THE PRIOR ART

Diesel engines with hydraulic electronic unit injectors and high-pressure pumps for supplying high-pressure liquid for actuating the injectors are well known. U.S. Patent No. 6,460,510 discloses a pump assembly for supplying high-pressure liquid to fuel injectors where the assembly includes a high-pressure pump and an inlet throttle valve for controlling the volume of oil supplied to the pump. The inlet throttle valve is moved between open and closed positions. A spring biases the inlet throttle valve spool toward a full open position. Hydraulic fluid is supplied to the inlet throttle valve through a modulated relief valve to bias the spool toward a closed position. The relief valve is controlled by an analog voltage signal from the engine control module (ECM) proportional to the difference between the output pressure of the high-pressure pump and the desired output pressure of the high-pressure pump.

The conventional pump assembly works well and efficiently supplies high-pressure liquid to injectors. Nonetheless, this assembly flows some high-pressure liquid to sump with resultant energy loss and heat buildup. The assembly can be difficult to stabilize throughout the entire operating range of an engine.

Accordingly, there is a need for an improved pump assembly with improved efficiency and stability.

SUMMARY OF THE INVENTION

The invention is an improved solenoid regulated pump assembly and method for flowing high-pressure liquid to fuel injectors, inlet and exhaust valves and other hydraulically-driven devices with improved efficiency and stability.

The assembly includes a hydraulically actuated inlet throttle valve and a hydraulic circuit for flowing high-pressure outlet liquid to the inlet throttle valve and venting liquid from the inlet throttle valve to sump using fast acting solenoid control valves responsive to digital (on -- off) signals from the ECM. The signals indicate whether the output pressure of the high-pressure pump is greater or less than the desired output pressure of the pump. Actuation of the fast acting solenoid valves connects the inlet throttle valve to the output passage and supplies high-pressure liquid to the inlet throttle valve or disconnects the inlet throttle valve from the output passage and vents the inlet throttle valve to sump to position the inlet throttle valve spool to a desired steady state

position in which the flow from the pump maintains the desired output pressure without flow of high-pressure liquid to sump.

The solenoid control valve operates very rapidly to shift valve members between fully opened and fully closed positions without modulating the flow through the valve. The valving members are preferably small to reduce inertial forces and permit fast movement between the full open and full closed position so that the assembly rapidly moves the inlet throttle spool to the desired position.

The improved pump assembly improves the fuel economy of the engine and decreases the need to dissipate heat by reducing the volume of high-pressure oil flowed through the system and to sump. During steady state operation of the engine, no high-pressure liquid is flowed directly to sump through the system. The rapid response time for the assembly reduces the volume of high-pressure liquid used. The assembly has a fast response time and is stable.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawings illustrating the invention, of which there are six sheets and six embodiments.

DESCRIPTION OF THE DRAWINGS

Figures 1-3 illustrate circuit diagrams for three embodiments of the invention; and

Figures 4-6 illustrate three additional embodiments.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Six pump assemblies are disclosed. Each assembly includes a high-pressure pump and a hydraulically actuated spool-type inlet throttle valve, of the types disclosed in U.S. patent No. 6,460,510.

The inlet throttle valve includes a spring which biases the valve spool toward a full open position for flowing a high volume of oil to the high-pressure pump. A pressure chamber at one end of the spool is supplied with pressurized oil for biasing the valve spool against the spring toward a minimum flow or closed position restricting the volume of oil flowed to the high-pressure pump.

In each pump assembly, hydraulic fluid is flowed to and vented away from the inlet throttle valve by fast acting solenoid actuated control valves in response to signals from the electronic control module (ECM). Each system is part of an internal combustion engine with components actuated by high-pressure fluid, typically a diesel engine with hydraulic electronic unit fuel injectors. The pump assemblies may actuate other components including inlet and exhaust valves.

Figure 1 illustrates pump assembly 10 for an internal combustion engine having an ECM, a sump 12 for collecting engine oil and a low pressure or lube pump 14 for flowing oil from the sump to the lubrication system for the engine through low pressure line 16. The engine includes a number

of hydraulically actuated fuel injectors 18 and a high-pressure output line 20 extending from assembly 10 to the injectors.

Assembly 10 includes a high-pressure pump 22 driven by the internal combustion engine and inlet throttle valve 24. Low pressure inlet line 26 extends from line 16 to an inlet port of valve 24. Inlet passage 28 extends from an outlet port of the inlet throttle valve to the inlet port of pump 22.

High-pressure outlet line 20 is connected to the high-pressure outlet port of pump 22. Pressure sensor 30 is connected to line 20 to send a pressure signal to the ECM proportional to the pressure in line 20.

Inlet throttle valve 24 includes a valving spool movable between open and closed positions to throttle inlet flow of oil to pump 22. Spring 32 biases the spool toward the full open position. The spool comprises a piston on the end of the spool away from spring 32 which faces a pressure chamber in the valve communicating with pressure line 34. The pressure in the chamber biases the spool toward the closed position. The position of the spool in the valve, and the flow area of the inlet throttle valve, are determined by a pressure balance between the spring force and the hydraulic force acting on the spool. Increased pressure in the chamber moves the spool toward the closed position to reduce flow to pump 22. Correspondingly, decreased pressure in the chamber allows spring 32 to move

the spool toward the open position to increase flow to pump 22.

High-pressure oil from line 20 is flowed to the inlet throttle valve 24 through fast acting solenoid controlled valve 36. Oil is flowed from valve 24 to sump 12 through fast acting solenoid controlled valve 38. High-pressure branch line 40 extends from line 20 to the inlet port of valve 36. Line 42 extends from the outlet port of valve 36 to line 34. Line 34 extends from the inlet throttle valve 24 to the inlet port of valve 38. Line 44 extends from the outlet port of valve 38 to sump 12.

Solenoid controlled valves 36 and 38 each include a valving member, which may be a spool or a poppet, and a spring 46 biasing the valving member toward a closed position, preventing flow of oil through the valve. Each valve also includes a solenoid 48 connected to the ECM. When actuated, each solenoid moves the valving member to an open position. Valve 36 flows high-pressure oil from line 20 to the inlet throttle valve 24 to bias the spool toward the closed or minimum flow position. Valve 38 drains oil from inlet throttle valve 24 to allow spring 32 to bias the spool toward the open position. The valves 36 and 38 are fast acting, permitting very rapid control of valve 24 in response to signals from the ECM.

During operation of the engine, pressure sensor 30 and other engine sensors provide information to the ECM which, in turn, generates output signals to solenoids 48 of valves

36 and 38. When the desired pressure in line 20 is greater than the sensed pressure in line 20, the ECM deactivates solenoid 48 in valve 36 so that spring 46 closes the valve. At the same time, the ECM actuates solenoid 48 of valve 38 to open the valve and vent the inlet throttle valve to sump 12. Hydraulic pressure acting on the inlet throttle valve spool is reduced to allow spring 32 to shift the inlet throttle valve spool toward the full open position to increase the flow of low pressure oil to pump 22 and the volume of oil pumped into line 20 thereby increasing the pressure in line 20.

When the sensed pressure in line 20 is greater than the desired pressure in line 20, the ECM actuates solenoid 48 of valve 36 to open the valve and deactuates the solenoid 48 of valve 38 to close the valve. High-pressure fluid is flowed to the inlet throttle valve to bias the spool toward the closed position to reduce the volume of high-pressure oil flowed to pump 22 and output line 20 and reduce the pressure in the line. By appropriate selective actuation and deactuation of the solenoids of valves 36 and 38, the inlet throttle spool is positioned as required to maintain the desired pressure in line 20.

An advantage of pump assembly 10 is that the inlet throttle spool remains in a fixed position when both solenoids of valves 36 and 38 are not actuated to facilitate steady-state operation of the engine. During steady state operation valve 36 and 38 are closed to prevent flow of

high-pressure liquid from line 20 to the sump. Reduction of the volume of high-pressure liquid flowed to the sump increases engine efficiency and reduces heat formation and the need to dissipate released heat.

In the event of an over pressure in line 20, both valves 36 and 38 may be opened to flow oil directly to sump 12 and rapidly decrease the output pressure. Each open valve 36, 38 forms a restriction in the flow of high-pressure liquid from line 20 to sump. These restrictions assure that line 34 and the inlet throttle valve is maintained at a sufficiently high-pressure to shift the inlet throttle spool rapidly toward the closed position during the period both valves 36 and 38 are open to flow oil directly to sump so that flow to pump 22 and line 20 is reduced.

In pump assembly 10, fast acting solenoid valves 36 and 38 are normally closed. Assembly 10 may be modified by providing normally open solenoid control valves in place of disclosed valves 36 and 38. In such a modified assembly, both valves are closed when energized. This arrangement has the advantage that the inlet throttle spool is always shifted to a full open position when the system is shut down, and valve 38 is opened to permit spring 32 to shift the inlet throttle valve spool to the open position and flow oil to sump. The inlet throttle valve will be wide open before start up, a requirement for hydraulic electronic unit injector diesel engines.

Figure 2 illustrates a second embodiment of the invention and includes elements corresponding to elements of the first embodiment. These elements are identified by the same reference numbers used in describing the first embodiment and function as previously described.

High-pressure oil from line 20 is flowed to and from the inlet throttle valve 24 through dual solenoid controlled valve 136. High-pressure branch line 138 extends from line 20 to an inlet port of valve 136. Line 134 extends from the work port of valve 136 to the inlet port of valve 24. Line 140 extends from an outlet port of valve 136 to sump 12.

Valve 136 includes a valving member or spool having a null position and end positions connecting line 138 to line 134 or connecting line 134 to line 140. Springs 142 and 144 bias the spool to the null position, preventing flow of oil through the valve. The valve also includes solenoids 146 and 148 actuated by the ECM. When solenoid 146 is actuated, the spool is shifted to connect line 138 to line 134. When solenoid 148 is actuated the spool is shifted to connect line 134 to line 140.

When line 138 is connected to line 134, high-pressure oil from line 20 flows to the inlet throttle valve 24. When line 134 is connected to line 140, oil from valve 24 flows to the sump 12. The solenoids 146 and 148 are fast acting, permitting rapid movement of the spool in valve 24 in response to signals from the ECM.

During operation of the internal combustion engine, the fast acting dual valve 136 controls the position of the spool in inlet throttle valve 24 to throttle the flow of inlet oil through passage 28 to pump 22. Inlet oil supplied to pump 22 is pumped to increase the pressure of the oil in line 20 supplied to injectors 18. If desired, an accumulator may be provided in passage 20.

During operation of the engine, pressure sensor 30 and other sensors provide information to the ECM which, in turn, generates output signals to solenoids 146 and 148 on dual valve 136. When the sensed pressure in line 20 is greater than the desired pressure in line 20, the ECM actuates solenoid 146 and deactuates solenoid 148 so that the spool on valve 136 shifts to connect line 138 with line 134. This allows high-pressure oil from line 20 to flow to inlet throttle valve 24, move the spool in the inlet throttle valve toward the closed position, decreasing the flow to pump 22 and decreasing the pressure in line 20.

Correspondingly, when the sensed pressure in line 20 is lower than the desired pressure in line 20, the ECM actuates solenoid 148 and deactuates solenoid 146 so that the spool on valve 136 is shifted to connect line 134 with line 140. This allows pressurized fluid in valve 24 to flow to sump 12, decreasing the pressure in the chamber in inlet throttle valve 24 and allowing the spool to move toward the open position. This increases the volume of high-pressure oil flowed into line 28 and increases the output of pump 22 and

the pressure in line 20. By appropriate selective actuation of the solenoids on valve 136 the inlet throttle spool is positioned as required to maintain desired output pressure.

Figure 3 illustrates a third embodiment of the invention and includes elements corresponding to the elements in the first and second embodiments. These elements are identified by the same reference numbers used in discussing the first embodiment.

Pump assembly 210 is part of an internal combustion engine having an ECM, and includes a sump 12, low pressure pump 14, inlet throttle valve 24, high-pressure pump 22, injectors 18 and as previously described.

High-pressure oil from line 20 is flowed to the inlet throttle valve 24 through solenoid controlled valve 220. High-pressure branch line 222 extends from line 20 to an inlet port of valve 220. Line 224 extends from the outlet port of valve 220 to an inlet port of valve 24. A branch of line 224 extends from line 224 through bleed orifice 226 to sump 12.

Solenoid controlled valve 220 has a valving member or spool and a spring 228 biasing the member toward a closed position, preventing flow of oil through the valve. The valve also includes a fast acting solenoid 230 connected to the ECM. When actuated, the solenoid moves the spool to an open position. Valve 220 flows high-pressure oil from line 20 to the inlet throttle valve 24 to bias the spool toward the closed or minimum flow position. Oil in line 224 flows

to the sump through bleed orifice or restriction 226. Valve 220 is fast acting, permitting very rapid opening and closing of valve 24 in response to signals from the ECM.

During operation of the engine, pressure sensor 30 and other sensors provide information to the ECM which, in turn, generates output signals to solenoid 230 on valve 220. When the sensed pressure in line 20 is greater than the desired pressure in line 20, the ECM energizes solenoid 230 so that the valving member on valve 220 is shifted to an open position. The valve flows high-pressure oil from line 20 to inlet throttle valve 24, moving the spool on the inlet throttle valve toward the closed position, decreasing the flow to pump 22 and decreasing the pressure in line 20. The pressure drop across restriction 226 establishes a pressure in line 224 to shift the inlet throttle spool against spring 32.

When the sensed pressure in line 20 is less than the desired pressure in line 20 the ECM deenergizes solenoid 230 so that the spool on valve 220 is closed. This cuts off the flow of high-pressure oil from line 20 to inlet throttle valve 24, reduces the pressure acting on the spool and moves the spool toward the open position, increasing the flow to pump 22 and increasing the pressure in line 20.

Bleed orifice 226 allows for a constant flow of fluid in line 224 to the sump 12. When valve 220 is closed, excess pressurized fluid in line 224 returns to sump 12 facilitating opening of valve 24.

In pump assemblies 10, 110 and 210 the valves have fast acting solenoids which shift the valving members rapidly between open and closed positions in response to signals received from the ECM. The ECM signals sent to the solenoids of these valves are digital signals, that is, a signal is either "on" or "off." An ECM "on" or "off" signal indicates whether the measured output pressure in line 20 is greater than or less than the desired output pressure. The solenoids of the valves controlling flow to and from the inlet throttle valves are actuated or deactuated during the interval of ECM "on" and "off" signals.

In the embodiments of Figures 1 and 2, digital solenoid control valves permit steady state operation of the engine with the solenoid controlled valves closed to prevent flow of liquid to or from the inlet throttle valve. In this position, the inlet throttle valve cannot move and the closed valves prevent flow of high-pressure fluid to the sump with resultant energy loss and generation of heat.

Figures 4, 5 and 6 illustrate pump assemblies 10', 110' and 210' which are identical to previously described assemblies 10, 110 and 210 with the exception of orifices provided in the flow paths between pressure output line 20 and inlet throttle valve 24. The orifice provides a pressure drop between the outlet pressure line and the inlet throttle valve to slow movement of the inlet throttle valve spool toward the closed position when a valve opens quickly

and liquid at output pressure is flowed to the inlet throttle valve.

In Figure 4, restriction 60 is provided in line 34 between line 42 and inlet throttle valve 24. When valve 36 is opened high-pressure outlet liquid flows from line 20 through valve 36, line 34 and orifice 60 to the inlet throttle valve. The orifice 60 reduces the pressure of the liquid flowing to the inlet throttle valve to slow response movement of the inlet throttle valve spool toward the closed position. Restriction 60 prevents bottoming of the inlet throttle valve spool on the body of the valve with possible injury to the spool and valve. Preferably restriction 60 reduces the pressure of fluid flowing from line 20 to the inlet throttle valve so that during rapid shutdown of the engine from high speed operation with high output pressure in line 20 the inlet throttle valve is moved in a closing direction to a position flowing a minimum volume of oil to pump 22 sufficient for low RPM or idle operation of the engine.

Restriction 60 is provided in the flow path from high-pressure output line 20 to the inlet throttle valve 24. The restriction need not be located in line 34 as illustrated. Alternatively, the restriction may be located in line 40, in valve 36 or in line 42.

Figure 5 illustrates control system 110' which is identical to control system 110 with the exception that a restriction 70 is provided in line 134 between valve 136 and

inlet throttle valve 24. Restriction 70 reduces the pressure of high-pressure liquid flowed from outlet line 20 to the inlet throttle valve in order to prevent overshooting of the inlet throttle valve when valve 136 connects line 138 to line 134, as previously described. Restriction 70 may be located in line 134, as illustrated, in line 138 or in valve 136, again as described.

Control assembly 210' is identical to assembly 210 with the exception of restriction 80 located in the branch of line 224 leading directly to inlet throttle valve 24. Restriction 80 reduces the pressure of high-pressure liquid flowed from passage 20, through passage 222, valve 220 and passage 224 to the inlet throttle valve, as previously described. The restriction may be located in passage 222, in valve 220 or in the portion of passage 224 adjacent valve 220 as desired.

The solenoid control valves are preferably acting in order to respond quickly to digital signals received from the ECM. Preferably, the solenoid control valve should be of the poppet type where the solenoid rapidly moves a low mass poppet into and out of engagement with a seat. Reduction of the mass of the valving member or poppet improves response time of the valve and, consequently, response of the pump assembly to signals from the ECM.

While I have illustrated and described a preferred embodiment of my invention, it is understood that this capable of modification, and I therefore do not wish to be

limited to the precise details set forth, but desire to avail myself of such changes and alternations as fall within the purview of the following claims.